THE CLASSIFICATION OF PROTOPHYTA

Including a Revision of the Families, and a Rearrangement of the North American Genera

By CHARLES E. BESSEY

Recent studies of the structure of the cell of the protophytes by Professor Kohl of Marburg[1] have given additional interest to this group of primitive plants. He has shown that instead of being composed of non-nucleated cells, they possess primitive nuclei, which develop simple karyokinetic figures during division. The nucleus is not surrounded by a nuclear membrane, and is thus not sharply set off from the surrounding cytoplasm. In the living cell its periphery is extended into many pseudopod-like protrusions which penetrate the cytoplasm, even reaching the cell wall at times. Kohl finds genuine chloroplasts imbedded in the usually bluish or brownish cytoplasm.

For many years I have been giving such attention to the general classification of the protophytes as the time at my disposal would allow, and about six years ago put my conclusions into manuscript. The recent revival of interest in the blue-green algae has suggested to me that it might be helpful to other students of these simple plants to have these results before them. The manuscript is now printed in essentially its original form. In it I have attempted to make such an arrangement of the families and genera as would conform to my ideas of their probable evolution.

I regard the group as consisting of autonomous plants, and while there may be a few which are merely forms or stages of other plants, I am convinced that the number of such is small, and further that in all such cases *they are still protophytes*. The protophyte cell is quite too characteristic to be mistaken for anything else, and we may rest assured that none of these plants are earlier stages of any of the Chlorophyceae, with their distinctly nucleated cells.

[1] Ueber die Organisation und Physiologie der Cyanophyceenzelle und die mitotische Teilung ihres Kernes, von Dr. F. G. Kohl, Professor der Botanik an der Universität Marburg. Mit 10 lithographischen Tafeln. Verlag von Gustav Fischer in Jena. 1903.

It will be observed that in the arrangement of the protophytic genera I have not separated the colorless ones from those which possess chlorophyll. In other words the "bacteria" are here regarded as merely degraded (and therefore colorless) forms of the protophyte type. In the Family *Chroococcaceae* there is one genus of such colorless plants ("bacteria"), *viz.: Sarcina,* whose relationship to *Merismopedia* is evident. In the *Oscillariaceae* no less than ten of the twenty-two genera are composed of colorless plants.

BRANCH I—**PROTOPHYTA**

Protophytes; Water Slimes

Single cells or threads of cells; reproducing by fission and endospores. Plants minute, aquatic and normally blue-green, brownish green or fuliginous, and generally surrounded by gelatinous matter. Each cell contains a primitive nucleus not surrounded by a nuclear membrane, so that it is not well defined.

CLASS I. **SCHIZOPHYCEAE**

Fission Algae

With the characters of the branch. About 1,000 species are known.

KEY TO THE ORDERS.

Plants strictly one-celled,	1. *Cystiphorae.*
Plants few- to many-celled, forming threads,	2. *Nematogeneae.*

Order 1. CYSTIPHORAE

One-celled Protophytes

Plants one-celled, single or associated in loose groups in a gelatinous matrix. There is but one family.

Family 1. CHROOCOCCACEAE

Blue-green Slimes

Microscopic plants with the characters of the order.

KEY TO THE GENERA.

A. Cells globose (except in 7) dividing irregularly in three planes,
- I. Walls thin, — 1. *Chroococcus.*
- II. Walls thick, lamellated, — 2. *Gloeocapsa.*
- III. Walls confluent in colonies,
  - a. Colonies forming a stratum, — 3. *Aphanocapsa.*
  - b. Colonies globular, solid,
    - 1. Single, envelope thin, — 4. *Microcystis.*
    - 2. Aggregated, envelope thin, — 5. *Polycystis.*
    - 3. Single, envelope thick, — 6. *Anacystis.*
    - 4. Cells cuneate, — 7. *Gomphosphaeria.*
  - c. Colonies globular, hollow, — 8. *Coelosphaerium.*
  - d. Colonies irregular, latticed, — 9. *Clathrocystis.*

B. Cells globose, dividing regularly in two or three planes,
- I. Plants green, — 10. *Merismopedia.*
- II. Plants colorless (bacteria), — 11. *Carcina.*

C. Cells cylindrical, dividing in one plane only,
- I. Walls thin, — 12. *Synechococcus.*
- II. Walls thick, lamellated, — 13. *Gloeothece.*
- III. Walls confluent in colonies, — 14. *Aphanothece.*

A. CELL DIVISION IRREGULARLY IN THREE PLANES.

1. *Chroococcus* Naegeli. Cells globose, with thin walls, solitary or in small groups, blue-green, yellow, or reddish.—On damp rocks, walls and earth, and in ponds and springs. Diameter of cells 3 to 25 μ.

2. *Gloeocapsa* Kuetzing. Cells globose, with thick and lamellated walls, solitary or in small colonies surrounded by the walls of the mother-cells, blue-green, lead-colored, yellowish, or reddish.—On wet rocks, walls, and earth. Diameter of cells, cytoplasm 2.5 to 6 μ—including walls, 3 to 10 or 15 μ or more.

3. *Aphanocapsa* Naegeli. Cells globose, with thick, soft, colorless walls confluent into a gelatinous stratum in which are imbedded the blue-green cytoplasms.—On wet rocks, walls, and earth, and in ponds and streams. Diameter of cells, cytoplasm 2 to 8 μ, usually 3–5 μ.

4. *Microcystis* Kuetzing. Cells globose, minute with thin walls, densely aggregated into solid spherical colonies, each enclosed in a close thin envelope, blue-green, yellow, or orange.—On moist surfaces of wood, bark, earth, etc. Diameter of cells 1.5 to 4 μ; colonies 20 to 60 μ.

5. *Polycystis* Kuetzing. Cells globose, minute, with thin walls, densely aggregated into solid spherical colonies (as in *Microcystis*) of which several are enclosed in a thin envelope, blue-green, yellow,

or orange.—On moist surfaces and in pools. Diameter of cells 2 to 3 μ; colonies 50 to 100 μ.

6. *Anacystis* Meneghini. Cells globose, minute, with thin walls, densely aggregated into solid spherical colonies, each enclosed in a thickish envelope, pale blue-green, or brownish.—In springs and ponds. Diameter of cells 1 to 4 μ; colonies from 4 to 10 μ, to 150 to 300 μ.

7. *Gomphosphaeria* Kuetzing. Cells cuneate, in small colonies which are aggregated into solid spherical compound colonies with thickish envelopes, blue-green, yellow, or orange.—In pools and ditches. Diameter of cells about 4 μ; colonies 10 to 25 μ, or even 50 to 75 μ.

8. *Coelosphaerium* Naegeli. Cells globose, in small colonies, which are aggregated into compound globular, hollow colonies, the walls of the small colonies soon confluent and disappearing, blue-green and granulose.—In ponds. Diameter of cells 2 to 5 μ; of colonies 40 to 100 μ.

9. *Clathrocystis* Henfrey. Cells globose, aggregated into minute, gelatinous, irregular saccate or latticed colonies, blue-green.—Floating on ponds and pools. Diameter of cells about 3 μ; colonies 25 to 120 μ.

B. Cell Division Regularly in Two or Three Planes.

10. *Merismopedia* Meyer. Cells globose with thickish confluent walls, aggregated in flat, quadrate colonies of 4, 8, 16, 32, 64, etc., blue-green.—Floating in ponds. Diameter of cells 3 to 4.5 μ.

11. *Sarcina* Goodsir. Cells globose or at first angled, with thin walls, confluent in flat (or cubical) colonies of 4, 8, 16, 32, 64, etc.; colorless.—In intestinal or other animal fluids, and in stagnant pools. Diameter of cells 1 to 2, rarely 3 to 4 μ.

C. Cell Division in One Plane Only.

11. *Synechococcus* Naegeli. Cells cylindrical, or oblong, with thin walls, solitary or in small groups, blue-green, or sometimes yellowish or orange.—On wet rocks and in pools. Diameter of cells 7 to 16 μ.

12. *Gloeothece* Naegeli. Cells cylindrical or oblong, with thick colorless lamellated walls, often forming colonies enclosed within a common wall, blue-green, lead colored, yellowish, or reddish.—On wet rocks, earth and in pools. Diameter of cells 1.5 to 2.5 μ in our species, much larger or smaller in others.

13. *Aphanothece* Naegeli. Cells cylindrical, with the walls gelatinous, and confluent into a continuous roundish mass in which the blue-green, yellowish, reddish (or even green) cytoplasms are imbedded.—On wet ground. Diameter of cells 1.5 to 12 μ, commonly 3 to 8 μ.

Order 2. NEMATOGENEAE

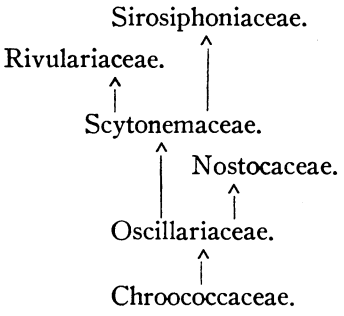
Filamentous Protophytes

Plants several- to many-celled, by division mainly in one plane, forming simple or branched threads, cell-walls often thickish and separating an outer continuous layer as a sheath which encloses the threads.

KEY TO THE FAMILIES.

A. Cells of the threads all alike, no heterocysts,
  Threads cylindrical, motile, 2. *Oscillariaceae.*
B. Cells differentiated, heterocysts present,
  I. Division of cells in one plane only,
    a. Threads moniliform, unbranched, 3. *Nostocaceae.*
    b. Threads cylindrical, sometimes spuriously branched, 4. *Scytonemaceae.*
    c. Threads tapering, sometimes spuriously branched, 5. *Rivulariaceae.*
  II. Division of cells ultimately in three planes,
    Threads with true branches, 6. *Sirosiphoniaceae.*

The following scheme illustrates the relationship of the families:



Family 2. OSCILLARIACEAE

Plants consisting of blue-green (exceptionally colorless) cylindrical, unbranched threads, which are usually composed entirely of disk-shaped cells separated by very thin transverse walls; longitudinal walls partly transformed into mucilage, forming a gelatinous investing sheath, or by fusing, a structureless jelly-mass in which

threads are imbedded (zoogloea). Reproduction by hormogones, *i. e.*, by the separation of few-celled sections of the threads, which afterwards increase in length by fission of their cells. Under favorable conditions the threads are motile, moving alternately forward and backward, at the same time curving and rotating.

KEY TO THE GENERA.

A. Tribe *Microcoleae*. Cells colored, green or greenish: usually two or more threads in each sheath.
  I. Threads not very numerous in each sheath,
    a. Sheaths firm, lamellose; threads not capitate,
      1. Sheaths hyaline or colored, containing two or more threads, 1. *Schizothrix*.
      2. Sheaths purple or salmon colored, containing one thread, 2. *Porphyrosiphon*.
    b. Sheaths soft and more or less diffluent,
      1. Sheaths hyaline, containing several capitate threads, cells short, 3. *Hydrocoleum*.
      2. Sheaths hyaline or dark yellowish, containing few, remote, not capitate threads; cells longer than broad, 4. *Dasygloea*.
  II. Threads many, crowded in each hyaline sheath,
    Sheaths not lamellose, more or less mucose, 5. *Microcoleus*.

B. Tribe *Lyngbyae*. Cells colored, green or greenish; threads solitary in the sheaths, or sheathless,
  I. Threads spuriously branched, or simple, apex always straight, sheaths firm,
    a. Threads spuriously branched,
      1. Threads free, branches often in pairs, 6. *Plectonema*.
      2. Threads in fascicles, branches single, 7. *Symploca*.
    b. Threads unbranched, free, 8. *Lyngbya*.
  II. Threads simple, apex sometimes curved, sheaths thin, mucose, hyaline, or apparently wanting,
    a. Sheaths diffluent, threads straight, 9. *Phormidium*.
    b. Sheaths apparently wanting in most cases,
      1. Threads straight or slightly curved, 10. *Oscillaria*.
      2. Threads spirally curved,
        a. Cells evident, 11. *Arthrospira*.
        b. Cells not evident, 12. *Spirulina*.

C. Tribe *Leptotrichiae*. Cells colorless. Threads without sheaths or nearly so,
  I. Normally filamentous,
    a. Threads with sheaths, 13. *Leptotrichia*.
    b. Threads without sheaths, 14. *Begiatoa*.
  II. Normally in short rods, sheathless and free (not aggregated as in III),
    a. Spores internal (endosporous),
      1. Cells straight or slightly curved,
        a. Spores smaller than the diameter of ordinary cells,
          i. Spores forming in ordinary cells,

(*a*) Cells with uniform protoplasm, 15. *Bacillus.*
(*b*) Cells with polar-diblastic protoplasm, 16. *Pasteurella.*
ii. Spores formed in special, swollen cells, 17. *Clostridium.*
b. Spores larger than the diameter of ordinary cells,
i. Spores in normal cells swollen in the middle, 18. *Cornilia.*
ii. Spores in special clavate cells, 19. *Vibrio.*
2. Cells spirally bent, 20. *Spirillum.*
b. Spores formed by the fission of cells (arthrosporous),
1. Cells cylindrical, straight, or curved, 21. *Pacinia.*
2. Cells ellipsoid, straight, 22. *Bacterium.*
III. Rods aggregated in plasmodium-like bodies,
a. Rods straight,
1. Forming external cysts, 23. *Chondromyces.*
2. Forming internal cysts, 24. *Polyangium.*
b. Rods curved. 25. *Myxococcus.*

Tribe I. MICROCOLEAE. Cells colored, green or greenish; usually two or more threads in each sheath.

1. *Schizothrix* Kuetzing. Sheaths firm, lamellose, hyaline, dark yellowish, or purplish, occasionally pale blue, containing a few loosely aggregated threads; cells often longer than broad, never much shorter, end cell straight, often attenuated, neither thick-walled nor capitate.—In water or moist places. Threads small, 1 to 3 μ, rarely more than 5 μ in diameter.

2. *Porphyrosiphon* Kuetzing. Sheaths firm, lamellose, purple or salmon colored, containing but one thread; cells as long as or shorter than broad, end cell obtuse, neither thick-walled nor capitate.—On moist earth. Threads rather large, 10 μ or more in diameter.

3. *Hydrocoleum* Kuetzing. Sheaths more or less mucose, or subamorphous, in age diffluent, sub-lamellose, hyaline, containing several threads; cells shorter than broad, end cell straight, more or less attenuated, capitate, its terminal wall thickened.—Aquatic, mostly marine plants. Threads rather large, usually more than 10 μ in diameter.

4. *Dasygloea* Thwaites. Sheaths mucose, diffluent, very much enlarged, hyaline or dark yellowish, containing a few remote threads, cells as long as or longer than broad, end cells straight, truncate. conical, neither thick-walled nor capitate.—In marshes. Threads rather small, 4 to 6 μ in diameter.

5. *Microcoleus* Demazieres. Sheaths more or less mucose, in some species eventually diffluent, not lamellose, hyaline, crowded

with many threads; cells not much longer than broad, end cell usually straight and attenuated (in one species capitate).—In water or on moist earth. Threads usually 4 to 10 μ in diameter, in some species less.

Tribe II. LYNGBYAE. Cells colored, green or greenish; threads solitary in the sheaths, or sheathless.

6. *Plectonema* Thuret. Sheaths firm, hyaline, rarely golden yellow; threads spuriously branched, singly or in pairs; cells mostly shorter than broad, end cell straight, rarely attenuated, not capitate. —Plants consisting of free threads growing on sticks and stones in ponds and streams. Threads in different species from 1 or 2 μ to nearly 50 μ in diameter.

7. *Symploca* Kuetzing. Sheaths firm or sub-mucose, thin; threads spuriously branched, singly; cells as long as, or longer than broad (in one species shorter), end cell straight, often somewhat attenuated, and sometimes with its walls slightly thickened.—Aquatic or terrestrial plants whose threads are usually collected in ascending fascicles. Threads small, mostly less than 3 or 4 μ in diameter (one species 6 to 14 μ).

8. *Lyngbya* C. Agardh. Sheaths firm, thin or later thick and lamellose, hyaline, rarely dark yellowish; threads unbranched; end cells straight, slightly if at all attenuated, sometimes with a thicker terminal wall (capitate).—Growing in salt, fresh, or thermal waters, or on the moist earth or the surfaces of other plants. Threads commonly 5 to 8 μ or even 20 to 30 μ in diameter (in a few species less than 2 μ).

9. *Phormidium* Kuetzing. Sheaths thin, mucose agglutinated, partly or entirely diffluent, hyaline; threads unbranched, sometimes moniliform; cells usually shorter than broad, end cell straight or curved, usually attenuated, sometimes capitate.—Aquatic or terrestrial plants. Threads usually about 3 μ or less in diameter, a few 10 to 11 μ.

10. *Oscillaria* Vaucher. Sheaths very thin, or apparently wanting in most cases; threads unbranched, cylindrical or moniliform, straight or slightly curved; end cell usually attenuated, straight or curved, terminal wall often thickened.—Growing in water or in wet places, forming dark green patches. Threads from very small (2 to 3 μ in diameter) to very large (50 to 60 μ).

11. *Arthrospira* Stizenberger. Sheaths apparently wanting;

threads unbranched coiled into a loose spiral; cells evident, end cells rounded, not capitate.—Aquatic. Threads in our species 5 to 8 μ in diameter (a Brazilian species 2 to 3 μ).

12. *Spirulina* Turpin. Sheaths apparently wanting; threads unbranched, coiled into a close spiral; cells not evident.—Aquatic. Threads very small (1 to 2 μ in diameter or less), moving actively with a spiral motion.

Tribe III. LEPTOTRICHIAE. Cells colorless, threads without sheaths, or nearly so. ("Bacteria.") *

13. *Leptotrichia* Trevisan. Threads long, slender, indistinctly septate, each enclosed in a thin sheath; usually not oscillating; not containing sulphur granules; base and apex usually unlike.—Saprophytes and parasites (on plants) in marine and fresh waters. Diameter of cells 0.4 to 3 μ.

14. *Beggiatoa* Trevisan. Threads long, indistinctly septate, not sheathed; usually oscillating freely; containing numerous sulphur granules; ends similar.—Saprophytes and parasites (on plants) in marine and fresh waters, common in warm sulphur springs. Diameter of cells 1 to 4 μ or even 16 to 20 μ.

15. *Bacillus* Cohn. Rods cylindrical or nearly so, straight or slightly curved, ends equal, rounded or truncate; cell protoplasm uniform; spores small; formed in ordinary cells.—Saprophytes in water and decaying organic matter, and parasites in the cells and fluids of many plants and animals. Rods 0.3 to 1 μ in diameter, and three or four times as long.

16. *Pasteurella* Trevisan. Rods usually cylindrical or ovoid, straight or slightly curved, ends equal, rounded or truncate; cell protoplasm polar-diblastic (*i. e.*, apparently denser at the poles); spores small, formed in ordinary cells.—Mostly parasites in the cells and fluids of animals, a few saprophytes in water and decaying organic matter. Rods 0.5 to 0.7 μ in diameter, and two to four times as long.

* The Myxobacteriaceae, which have been carefully studied by Dr. Roland Thaxter (Botanical Gazette, 17: 389. 1892; 23: 395. 1897; 37: 405. 1904) probably belong here. Their "rods" are evidently the same as the "rods" in the organisms described under the Leptotrichiae. They form plasmodium-like aggregations, on which rise aerial "pseudofructifications." The Myxobacteriaceae appear to be an aerial modification of the usual aquatic bacterial type. It may be suggested that they are xerophytic Leptotrichieae, while ordinary bacteria are hydrophytic. They may be regarded as a sub-tribe, with the characters given by Dr. Thaxter as in the text.

17. *Clostridium* Prazmowski. Vegetative rods cylindrical or ovoid, straight, or slightly curved, ends equal, rounded; cell protoplasm uniform; spores small, formed in special, swollen cells.—Mostly saprophytes in decaying organic matter, a few parasites in the fluids of animals. Rods 0.5 to 1 μ in diameter, and three to four times as long.

18. *Cornilia* Trevisan. Rods cylindrical, straight, ends equal, rounded or pointed; cell protoplasm uniform; spores large, formed in ordinary cells which then become swollen centrally or apically.—Mostly saprophytes in decaying organic matter, a few parasites in the fluids of animals. Rods 0.3 to 1 μ in diameter.

19. *Vibrio* Zopf. Vegetative rods cylindrical, sometimes joined into long threads slightly curved, or undulate-flexed, ends rounded, sometimes flagellate; spores large, formed in special, clavate-swollen cells.—Parasites in the fluids of animals, and saprophytes in decaying organic matter. Rods 0.5 to 0.8 μ in diameter, and from three to ten times as long.

20. *Spirillum* Ehrenberg. Rods cylindrical, spirally curved, ends sometimes flagellate; cell protoplasm uniform; spores small, formed in ordinary cells.—Saprophytes in decaying organic matter, and parasites in the cells and fluids of animals. Rods 0.5 to 3 μ in diameter, and of variable length, 5 to 10 μ, even to 100 or 200 μ.

21. *Pacinia* Trevisan. Rods cylindrical, straight or slightly curved, often forming straight, curved, or undulate threads; cell protoplasm uniform; spores formed by abstriction (arthrosporous).—Mostly parasites in the cells and tissues of animals, a few saprophytes in decaying organic matter. Rods 0.3 to 1 μ in diameter, and three to ten times as long.

22. *Bacterium* Ehrenberg. Rods short, ellipsoid, rarely cylindrical, straight, ends obtuse; cell protoplasm uniform; spores formed by abstriction (arthrosporous).—Saprophytes in decaying organic substances, rarely parasitic. Rods 0.5 to 2.5 μ in diameter, and three to four times as long.

Sub-tribe MYXOBACTERIACEAE. "Motile, rod-like organism, multiplying by fission, secreting a gelatinous base, and forming pseudoplasmodium-like aggregations before passing into a more or less highly developed cyst-producing resting state, in which the rods may become encysted in groups without modification or may be converted into spore masses."—They are mostly saprophytes.

The three genera at present recognized are characterized as follows:

23. *Chondromyces* Berkeley and Curtis. "Rods forming free cysts, in which they remain unmodified. Cysts various, sessile or borne on a more or less highly developed cystophore."—Eleven species have been described as growing on rotten wood, dung, and other organic matter.

24. *Polyangium* Link. "Rods forming large rounded cysts, one or more free within a gelatinous matrix raised above the substratum." —Six species, on wet wood, dung, etc.

25. *Myxococcus* Thaxter. "Rods slender, curved, swarming together after a vegetative period to form definite, more or less encysted sessile masses of coccus-like spores."—Seven or eight species, on decaying substances, dung, etc.

Family 3. Nostocaceae

Plants consisting of amber- or blue-green, more or less moniliform, unbranched threads, composed of globose or sub-globose cells, spores, and heterocysts; cell walls more or less transformed into mucilage forming a gelatinous investing sheath, or by fusing, a structureless jelly-mass in which the threads are imbedded. Reproduction in two ways, (1) by free-swimming hormogones of a few cells (4 to 12) which develop directly into new plants, or form rows of spores; (2) by spores formed in ordinary threads as well as in hormogones, which divide internally into minute chains of cells which are set free by the rupture of the old cell wall. The heterocysts are rounded, usually enlarged cells without granular contents, whose function is unknown.

Key to the Genera.

A. Heterocysts intercalated,
  I. Threads moniliform (*i. e.*, composed of rounded bead-like cells) globose or irregular,
    a. Flexuously curved, normally in gelatinous masses,
      1. Colored (sometimes very slightly), 1. *Nostoc.*
      2. Colorless (bacteria),
        a. Threads evident, 2. *Leuconostoc.*
        b. Cells in botryoid masses, 3. *Staphylococcus.*
        c. Cells solitary or in zoogloeae, 4. *Micrococcus.*
    b. Nearly straight,
      1. Colored,

a. Threads parallel, in a closed tube,	5. *Wollea.*
b. Threads free, or in gelatinous masses,	6. *Anabaena.*
2. Colorless (bacteria),	7. *Streptococcus.*
II. Threads cylindrical, nearly straight,	
a. Agglutinated in fascicles,	8. *Aphanizomenon.*
b. Each in a sheath,	9. *Nodularia.*
B. Heterocysts terminal,	10. *Cylindrospermum.*

1. *Nostoc* Vaucher. Threads mostly moniliform, flexuously curved, with or without a distinct sheath; cells globose, cask-shaped, or cylindrical; heterocysts intercalary (rarely terminal); spores intercalary, spherical or oblong.—Forming globose, nodulose, or irregular, amber- or pale-green gelatinous masses 1 mm. to 50 mm. or 100 mm. in diameter, in water or on moist ground. Threads small, 2 to 9 μ in diameter.

2. *Leuconostoc* Van Tieghem. Threads moniliform, curved, composed of globose, colorless cells.—Forming globose, nodulose, or irregular, white, gelatinous masses on beet-root sugar and the vessels used in its manufacture (also on leaves of plants, where they appear to grow in the sweetish exudate). Cells 0.8 to 1.2 μ in diameter.

3. *Staphylococcus* Ogston. Globose cells single, in pairs, short threads, or botryoid masses, colorless.—Parasites in the cells and fluids of animals, and saprophytes in decaying organic matter. Cells 0.3 to 2 μ in diameter.

4. *Micrococcus* Cohn. Globose or ovoid cells single, in short threads, or in irregular gelatinous masses (zoogloeae), colorless.—Parasites in the cells and fluids of animals, and saprophytes in decaying organic matter. Cells 0.15 to 1 μ, rarely 2 to 4 μ in diameter.

5. *Wollea* Bornet and Flahault. Threads blue-green, moniliform, nearly straight, sheaths confluent; cells oblong; heterocysts intercalary; spores intercalary, oblong.—Forming erect or floating cylindrical gelatinous masses enclosing many parallel agglutinated threads, in ponds. Threads small, 4 to 5 μ in diameter.

6. *Anabaena* Bory. Threads blue-green, moniliform, nearly straight, without a sheath, or but a vestige of one; cells globose or sub-globose; heterocysts intercalary; spores intercalary, globose, or elongated.—Floating free in ponds, or forming gelatinous masses on moist surfaces. Threads mostly small, 4 to 6 μ in diameter (one species 14 μ).

7. *Streptococcus* Bills. Threads moniliform, nearly straight, without a sheath; cells globose, colorless.—Parasites in the cells and

fluids of animals, and in decaying organic matter. Cells 0.2 to 2 μ in diameter.

8. *Aphanizomenon* Morren. Threads blue-green, cylindrical, nearly straight, without a sheath; cells cylindrical; heterocysts intercalary, large, sub-cylindrical; spores intercalary, large, cylindrical-elongated.—Threads 5 to 6 μ broad, agglutinated into small fascicles, floating free in ponds.

9. *Nodularia* Martens. Threads blue-green, cylindrical, nearly straight, each usually enclosed in a sheath; cells disk-shaped; heterocysts intercalary, compressed; spores intercalary, globose.—Threads 4 to 18 μ in diameter, floating free in ponds or forming an indefinite stratum on other aquatic plants.

10. *Cylindrospermum* Kuetzing. Threads blue-green, cylindrical, nearly straight, without a sheath; cells cylindrical; heterocysts terminal, globose or sub-globose; spores contiguous to the heterocysts, oblong or cylindrical.—Forming an indefinite stratum in ditches, on wet rocks, and on the ground. Threads small, 3 to 5 μ in diameter.

Family 4. Scytonemaceae

Plants consisting of cylindrical, green or brown, usually branched threads which are composed of more or less disk-shaped cells; end cells thin walled, dividing repeatedly in one plane, and thus increasing the length of the thread; longitudinal walls partly transformed into mucilage, forming a gelatinous investing sheath. Reproduction by hormogones and spores, as in *Nostocaceae*. Heterocysts intercalary and basal.

Key to the Genera.

A. Threads solitary in each sheath,	
I. Unbranched,	1. *Microchaete.*
II. With spurious branches usually in pairs,	2. *Scytonema.*
III. With spurious branches single,	
a. Threads fragile, plants terrestrial,	3. *Hassallia.*
b. Threads flexible, plants aquatic,	4. *Tolypothrix.*
B. Threads generally 2 to 6 in each sheath,	5. *Desmonema.*

1. *Microchaete* Thuret. Threads unbranched, solitary in each sheath; heterocysts basal and intercalary.—Minute plants of salt and fresh waters, growing in clusters or tufts about 1 mm. long, each thread 5 to 9 μ in diameter.

2. *Scytonema* Agardh. Threads solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of one or commonly two branches.—Aquatic or terrestrial plants composed of usually large threads, often several millimeters long forming interwoven mats; threads from 7 to 45 μ broad, commonly 12 to 20 μ.

3. *Hassallia* Berkeley. Threads minute, fragile, solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of a single branch; sheath thin, not mucilaginous.—Forming a green stratum on moist ground or stones. Threads 1 mm. or less long, 5 to 10 μ (or even 15) broad.

4. *Tolypothrix* Kuetzing. Threads larger, flexible, solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of a single branch; sheath thin.—Forming tufts 10 to 30 mm. high on plants and stones, or floating freely, in fresh waters. Threads 8 to 10 μ or even 15 to 18 μ broad.

5. *Desmonema* Berkeley and Thwaites. Threads usually 2 to 6 in each sheath, sub-dichotomously branched, a heterocyst at the base of each spurious branch; sheath thin.—Forming small, green tufts 5 to 6 mm. high on stones, etc., in streams and other fresh waters. Threads 9 to 10 μ or more in diameter.

Family 5. RIVULARIACEAE

Plants consisting of tapering, green or reddish, simple or spuriously branched threads, composed of nearly cylindrical (slightly tapering) cells; lower cells much larger and greener than the upper which form a slender, hyaline hair; longitudinal walls partly transfomed into mucilage, forming a gelatinous investing sheath. Reproduction by hormogones and spores formed in the thicker portion of the thread. Heterocysts usually at the base of the threads.

KEY TO THE GENERA.

A. Threads free, simple or spuriously dichotomo-corymbosely branched,
   I. Threads simple, or spuriously branched, the branches distinct and free, 1. *Calothrix.*
   II. Threads spuriously branched,
      a. Branches several (2 to 6) in each sheath, 2. *Dichothrix.*
      b. Branches very many (even to 100) in each sheath, 3. *Polythrix.*

B. Threads grown into crustaceous, hemispherical or globose masses,

I. Heterocysts basal,
  a. Threads simple, crowded parallel in crustaceous masses, 4. *Isactis*.
  b. Threads spuriously branched, crowded and radiating, forming a globose or hemispherical mass,
    1. No spores known, 5. *Rivularia*.
    2. Spores large, solitary, 6. *Gloeotrichia*.
II. Heterocysts intercalary, 7. *Brachytrichia*.

1. *Calothrix* Agardh. Threads simple or spuriously branched, the branches distinct and free; sheaths cylindrical, enclosing a single thread; heterocysts intercalary or basal, sometimes none.—Forming minute tufts or cushions a millimeter or so high on stones and other objects in fresh and salt waters, and on moist earth. Threads from 3 to 5 μ to 25 to 40 μ broad.

2. *Dichothrix* Zanardini. Threads spuriously dichotomous, 2 to 6 included in a common sheath; heterocysts basal or intercalary.—Forming minute tufts or cushions 1 to 20 mm. high on stones and other objects in fresh and salt waters. Threads usually 10 to 12 μ broad, sometimes 25 to 30 μ.

3. *Polythrix* Zanardini. Threads spuriously dichotomous, very many (even to 100) enclosed in a common sheath; heterocysts basal and intercalary.—Forming tufts and cushions 10 to 30 mm. high on stones in salt waters (Key West). Threads 5 to 6 μ broad.

4. *Isactis* Thuret. Threads simple or rarely spuriously branched, erect and parallel; sheaths hyaline or yellowish; heterocysts basal; spores unknown.—Marine plants whose crowded, parallel threads form small, flattish, crustaceous masses. Threads 7 to 9 μ broad.

5. *Rivularia* Roth. Threads spuriously branched, crowded and radiating; sheaths narrow to broad, hyaline or colored; heterocysts basal; spores unknown.—Forming small, globular or hemispherical masses a millimeter or so in diameter, in salt or fresh waters. Threads 2 to 14 μ broad.

6. *Gloeotrichia* J. Agardh. Threads spuriously branched, crowded and radiating; sheath enclosing the base of the thread, dissolving above, hyaline or colored; heterocysts basal; spores present, above the heterocysts; hormogones serial and numerous.—Forming globose or hemispherical masses, a millimeter or so in diameter (or 20 to 100 mm.), in fresh or brackish waters. Threads 4 to 9 μ broad.

7. *Brachytrichia* Zanardini. Threads spuriously much branched, parallel, flexuously curved; sheaths at first distinct, finally deliquescing; heterocysts intercalary.—Forming solid, or eventually

hollow, gelatinous masses, 6 to 60 mm. in extent, in which the threads are enclosed. Threads 5 to 6 μ broad.

Family 6. SIROSIPHONIACEAE

Plants consisting of cylindrical or irregular, greenish, brown, or blackish, sheathed and usually branched threads, at first consisting of a single row, but later mostly of several rows of cells; end cells usually dividing at first repeatedly in one plane only, and later in more than one plane, some of the latter again dividing repeatedly in one plane (parallel to the axis of the thread) thus originating branches; all walls of the cells more or less transformed into mucilage, the outer forming a gelatinous sheath for the thread, the inner separating the protoplasts; heterocysts intercalary (rarely terminal also). Reproduction by hormogones and spores, the latter formed by the change of disk-like cells toward the end of a thread into roundish resting spores, which germinate after a period of rest.

KEY TO THE GENERA.

A. Threads consisting of one row of cells, rarely of two rows, 1. *Haplosiphon.*
B. Threads commonly consisting of two or more rows of cells, 2. *Stigonema.*

1. *Haplosiphon* Naegeli. Threads creeping, consisting of one row of cells, rarely of two rows; branches erect, parallel.—Aquatic, cespitose-floccose, slender plants, forming green, blue-green, or at length brown tufts which are floating or attached. Threads 6 to 24 μ broad.

2. *Stigonema* Agardh. Threads commonly consisting of two or more rows of cells; branches irregular, spreading.—Terrestrial or aquatic, dark brown plants, forming expanded, slimy strata. Threads 7 to 10 μ, or even 45 to 90 μ broad.